



Search for multi-neutron system in extremely neutron-rich nuclei

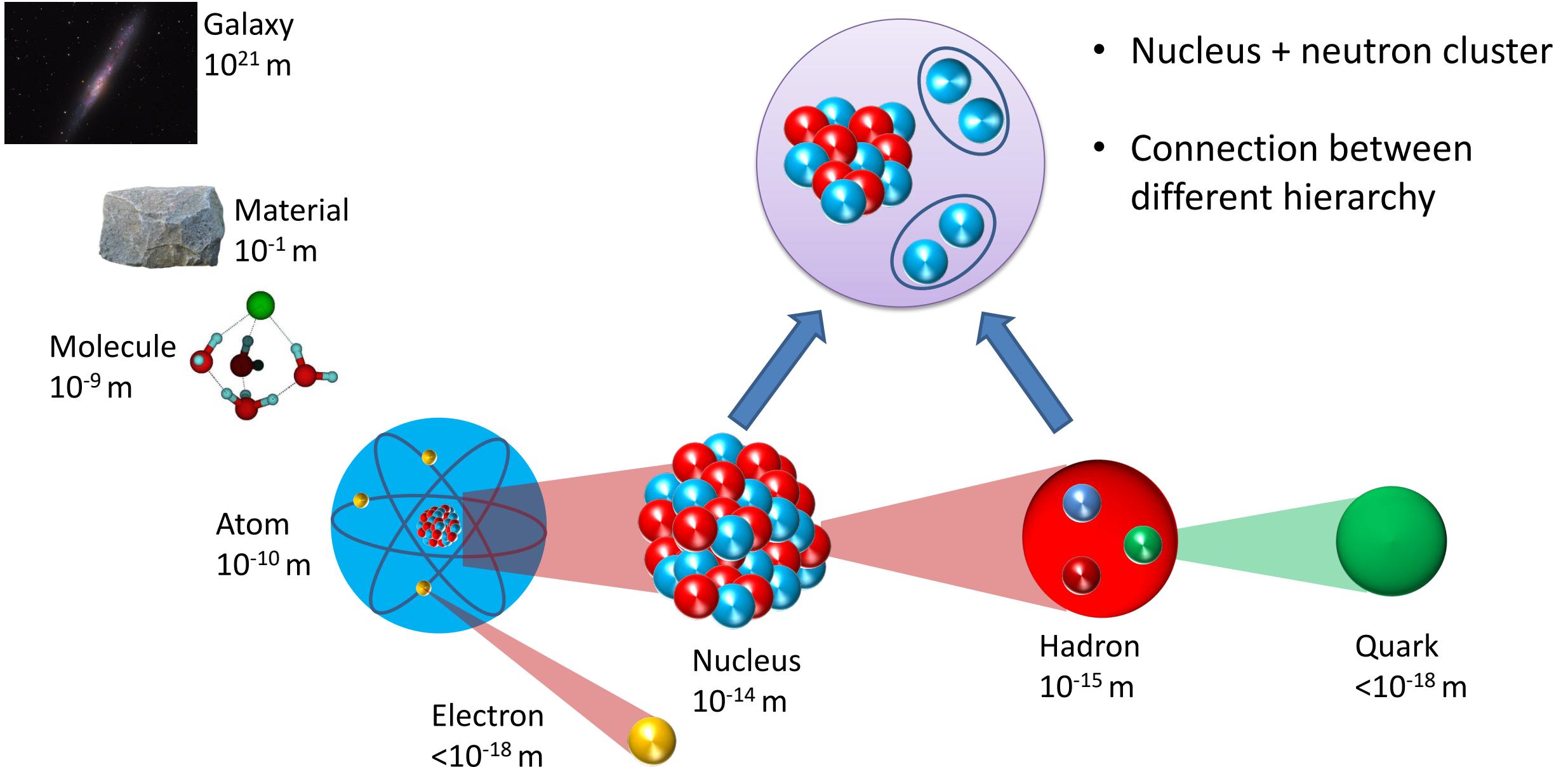
He Wang

Tokyo Institute of Technology

Content

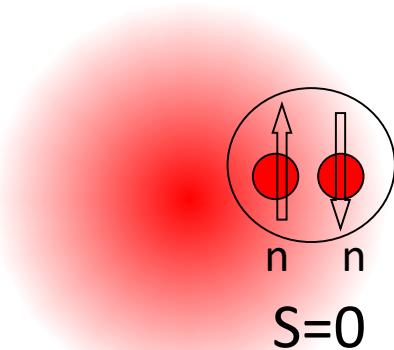
- Motivation
- Experiment details
- Status
- Summary

New insight for hierarchy



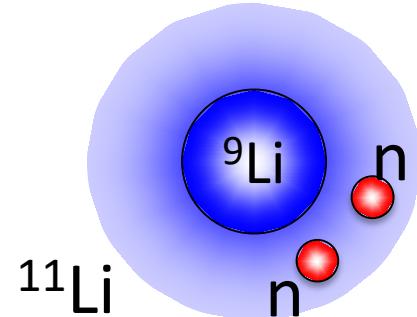
Possible multi-neutron systems

Di-neutron



2n Halo Nuclei?

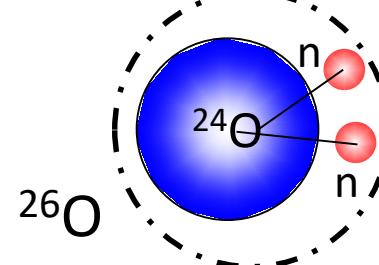
$$S_{2n} = 0.37 \text{ MeV}$$



T.Nakamura et al., PRL96, 252502 (2006).

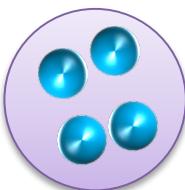
2n weakly-unbound nuclei?

$$S_{2n} = -0.018(5) \text{ MeV}$$

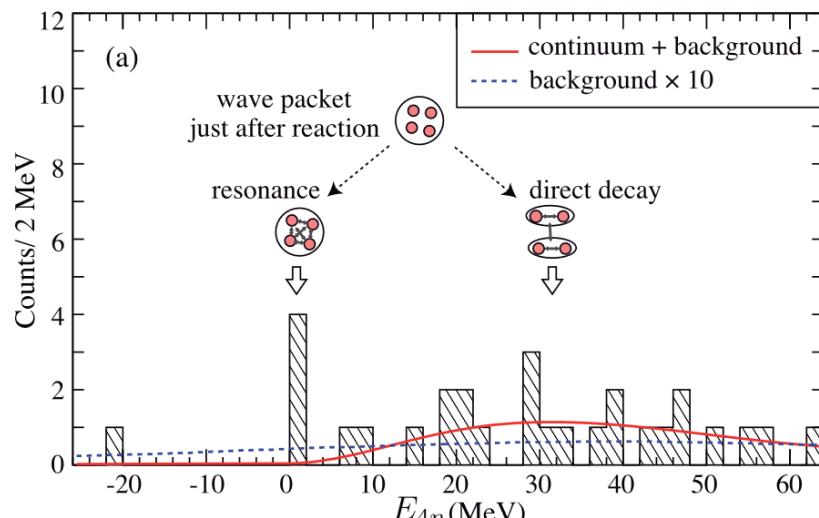


Y. Kondo et al., PRL116,102503(2016).

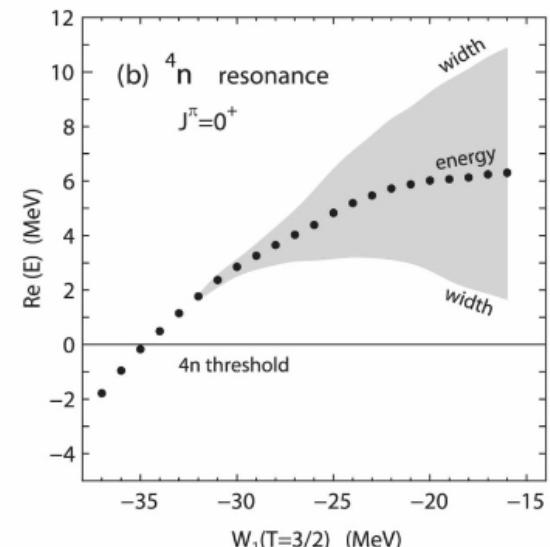
Tetra-neutron



- $T=3/2$ 3NF?
- Too strong attraction of 3NF, which makes ^4H bound
- More experimental evidence



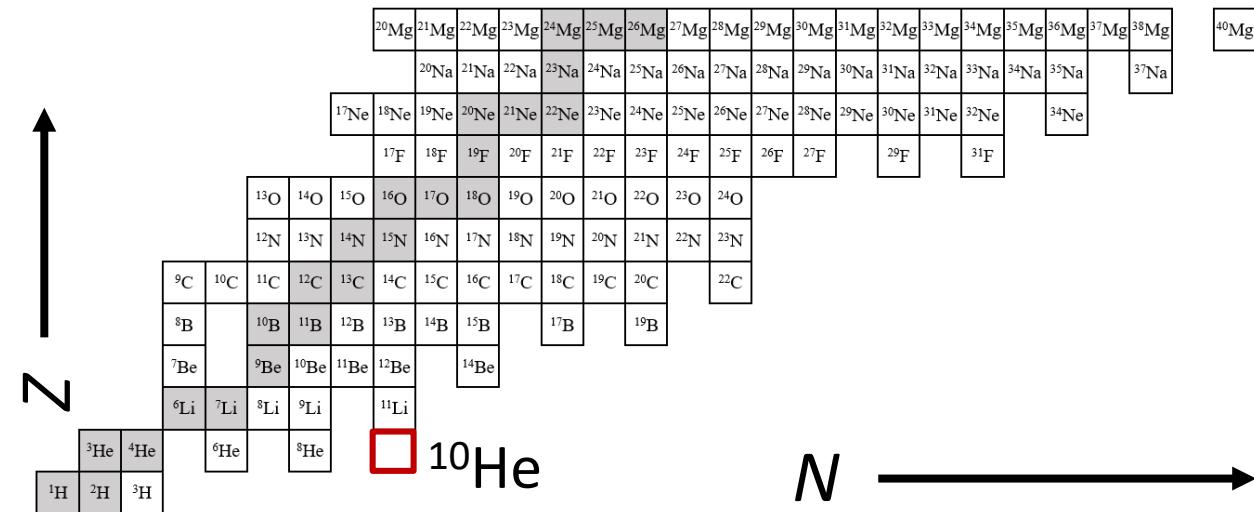
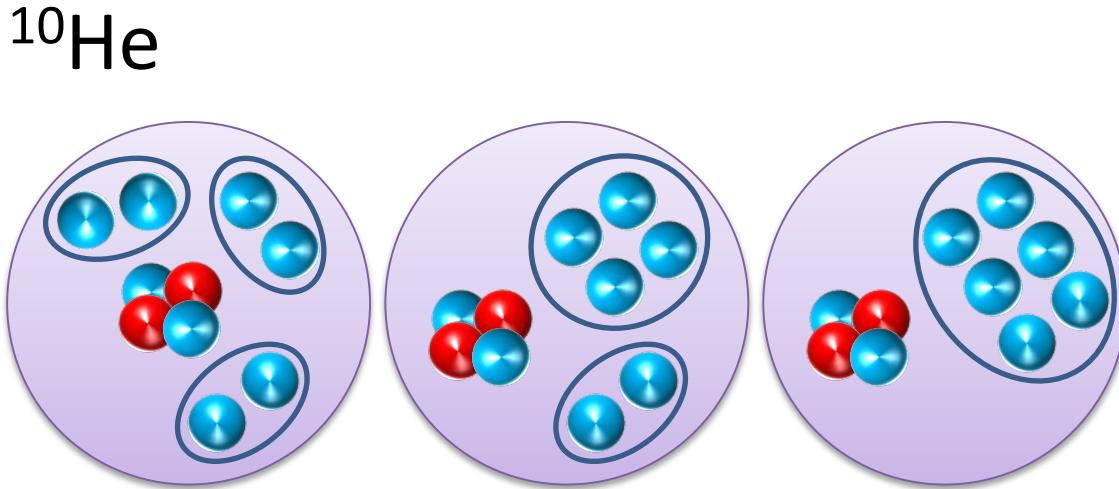
K. Kisamori et al., PRL. 116, 052501



E.Hiyama et al., PRC 93(2016)044004

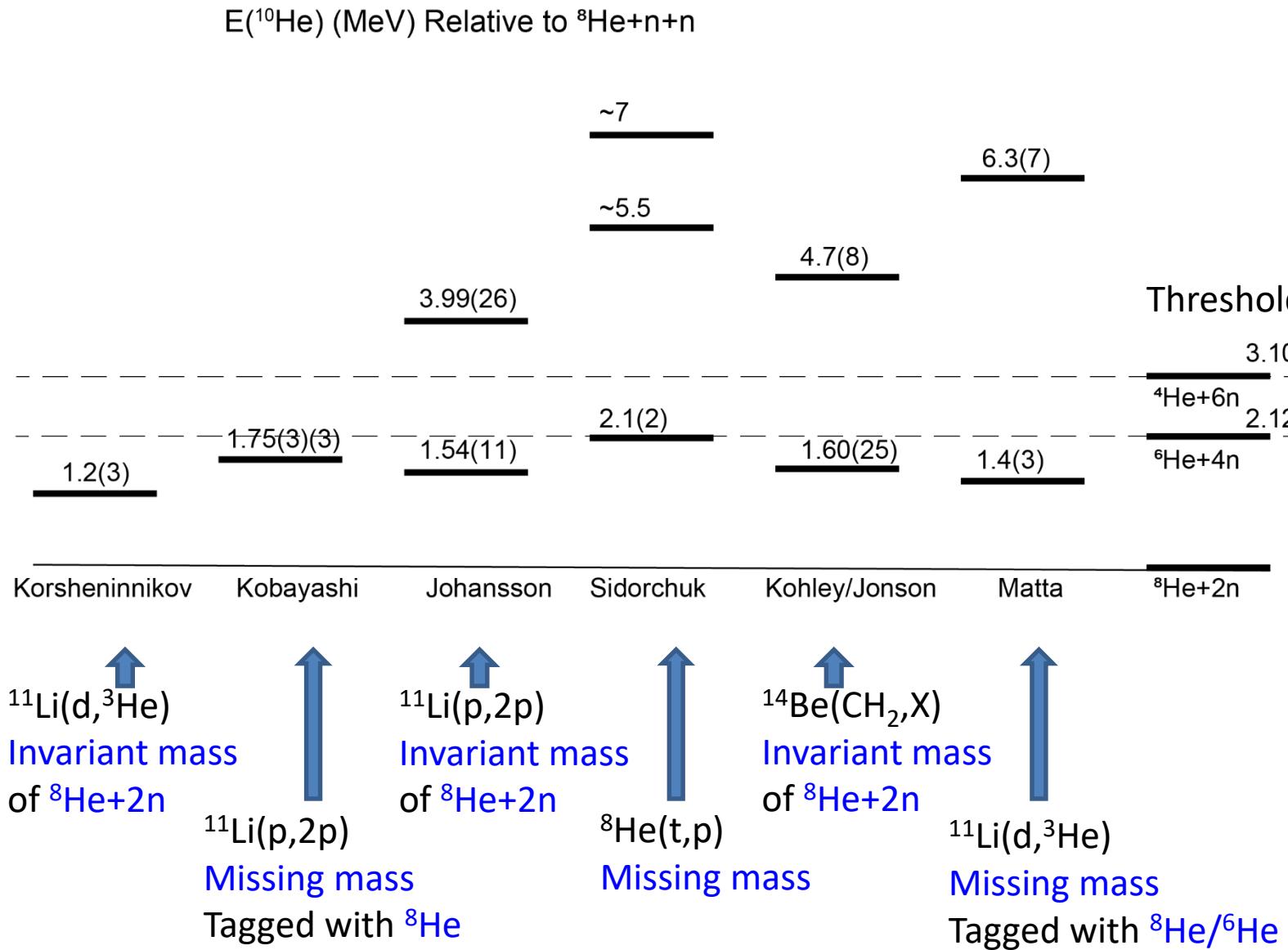
Search exotic neutron cluster

- Nuclei beyond neutron drip-line, ^{10}He (^4He and 6 neutrons)
- ($p, 2p$) reaction to access
- Intense neutron-rich ^{11}Li beam and advanced RI facility (SAMURAI) at RIBF



Di-neutron as new building blocks for nuclear structure?
Existence of Tetra-neutron, Hexa-neutron?

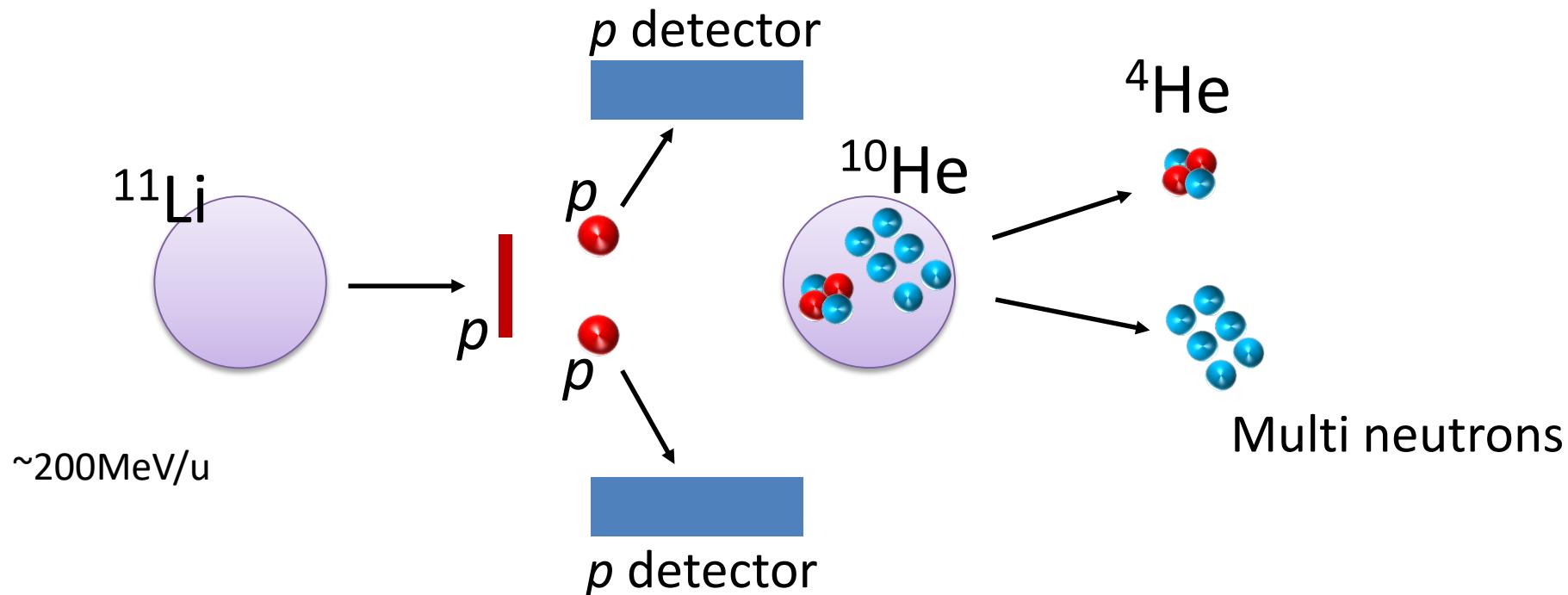
Deviations in previous measurements of ^{10}He



- g.s. ~ 1.4 MeV
- Excited states: Controversial

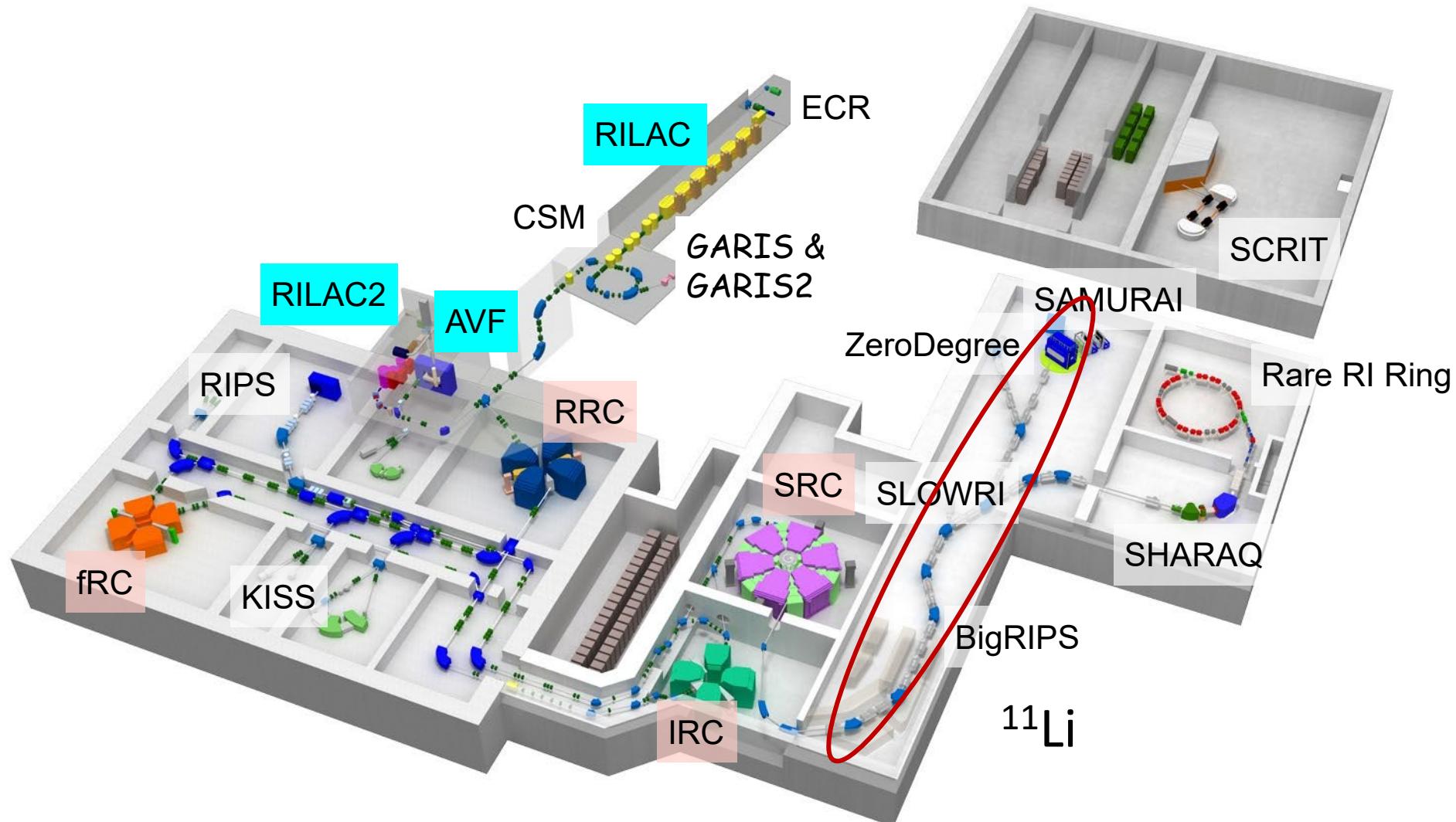
Experimental method

- ($p, 2p$) for neutron-rich nuclei
- Missing mass method



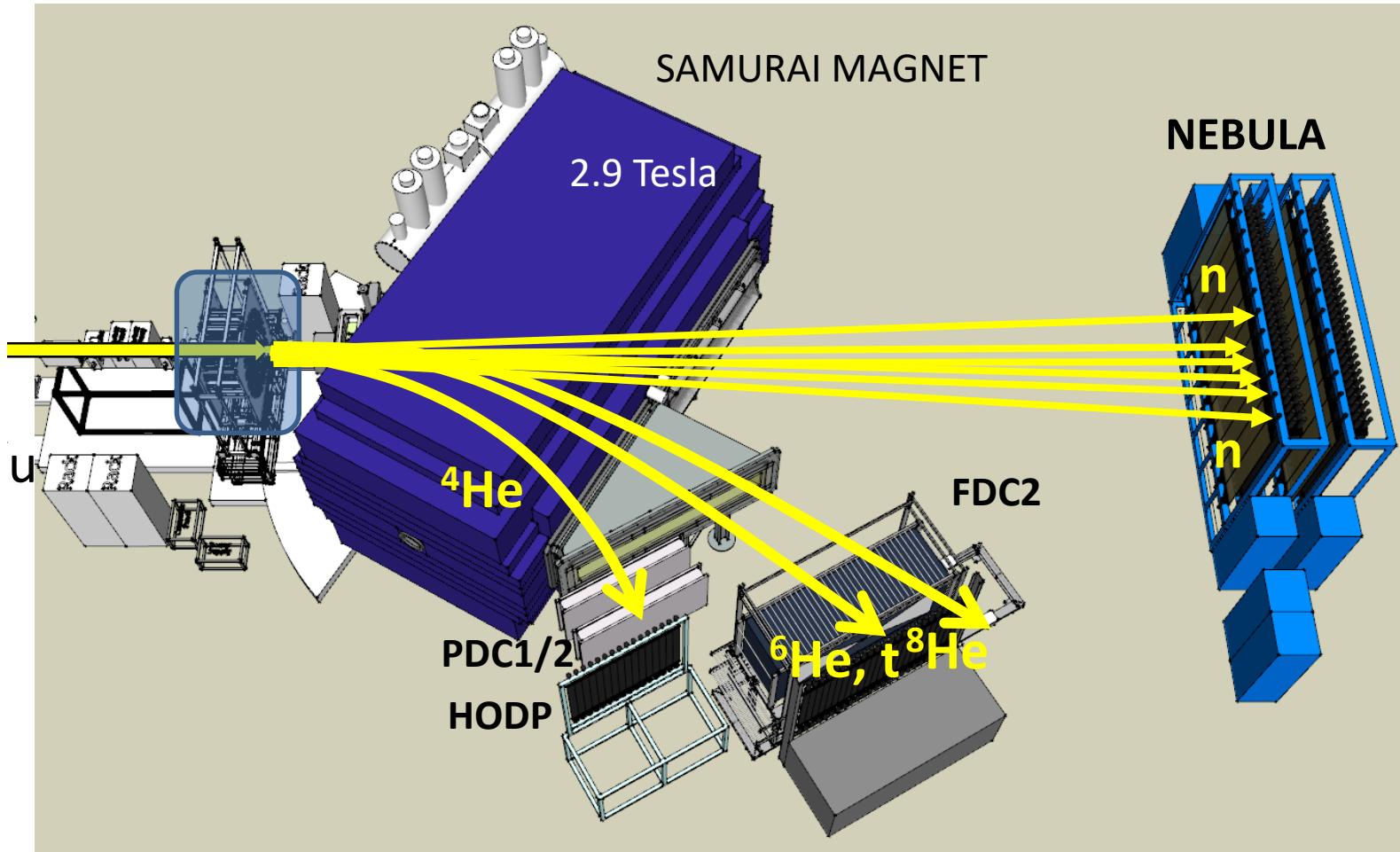
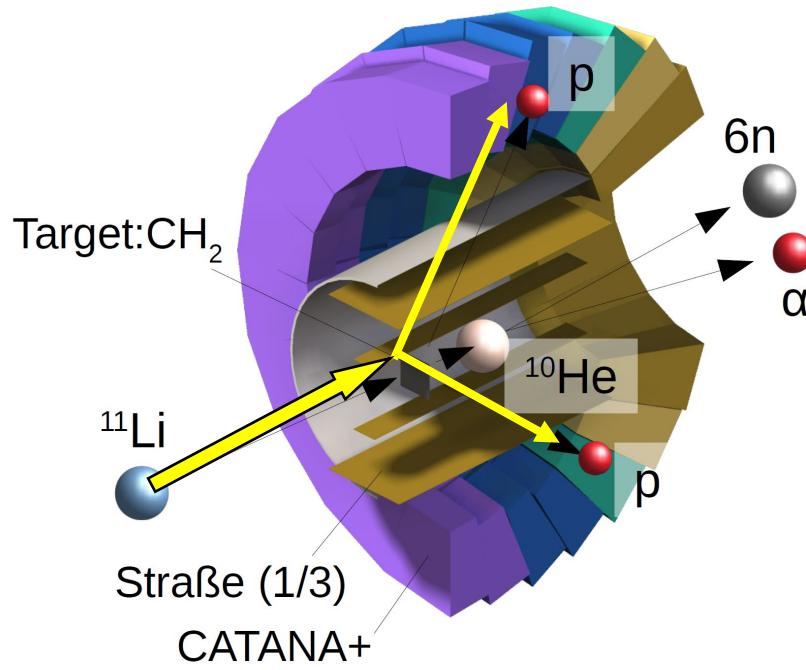
- Momentum and energies of two recoiled protons
- To reconstruct mass and excitation energies for ^{10}He

RI Beam Factory @ RIKEN



Experimental setup

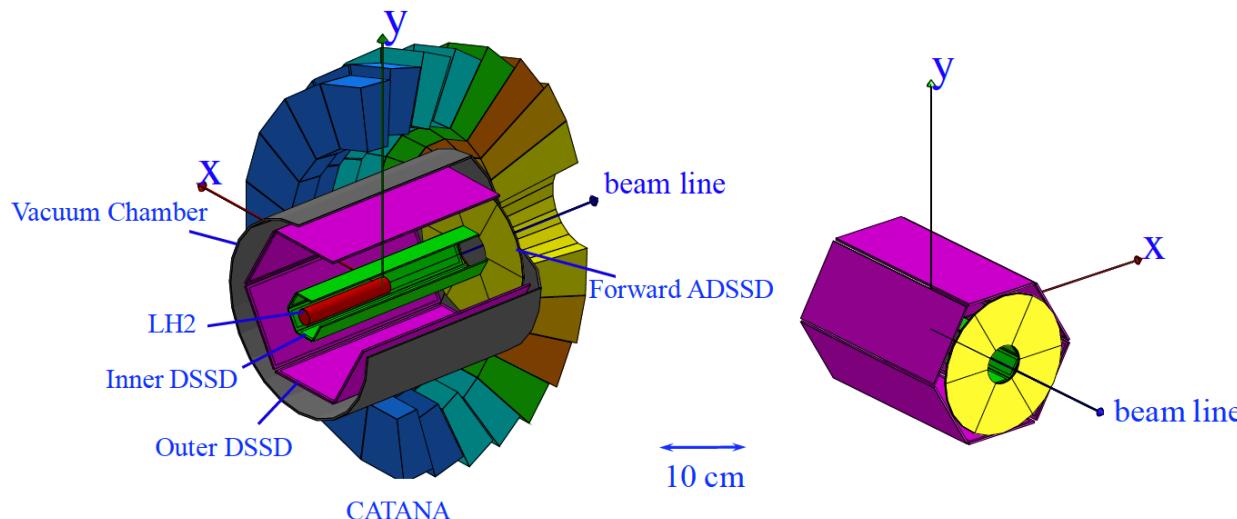
To tag recoiled proton in (p,2p)
→Angle and energy
→tracker and total E detector



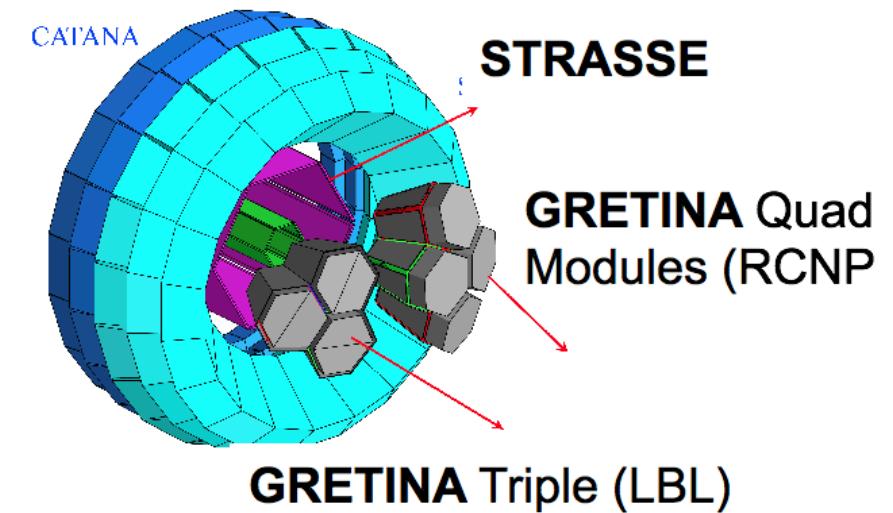
SRASSE and CATANA plus

- STRASSE: Silicon tracker
- CATANA plus: Total energy detector

1) Missing mass spectroscopy ($p, 2p$) and ($p, p\alpha$)



2) Missing mass + High resolution γ -ray spectroscopy



Approved Construction proposal @ RIBF NP1812:

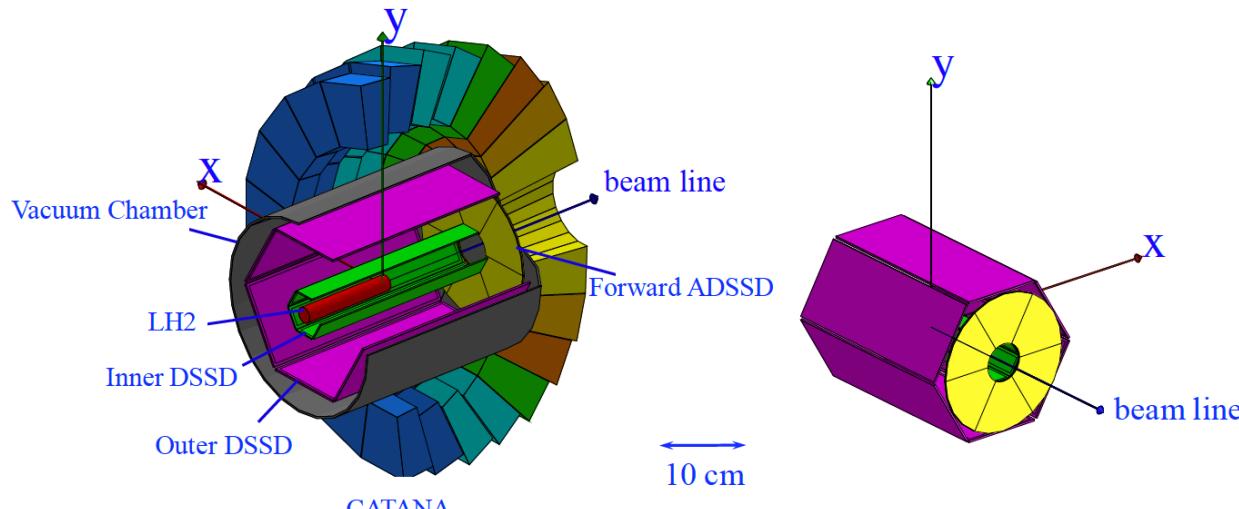
[Large-acceptance missing mass setup, CATANA PLUS and STRASSE at SAMURAI](#)

Spokespersons: Takashi Nakamura (TiTECH) and Alexandre Obertelli (TU Darmstadt)

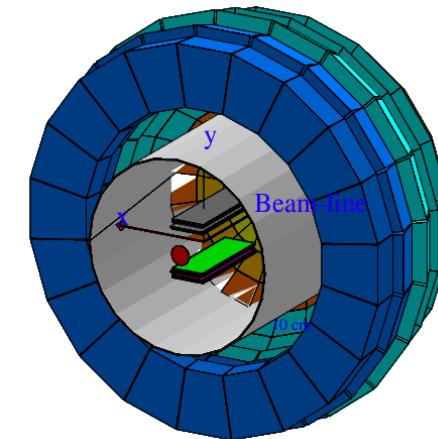
SRASSE and PFAD

- STRASSE: Silicon tracker
- CATANA plus: Total energy detector
- PFAD: Prototype
- 1/3 Si trackers

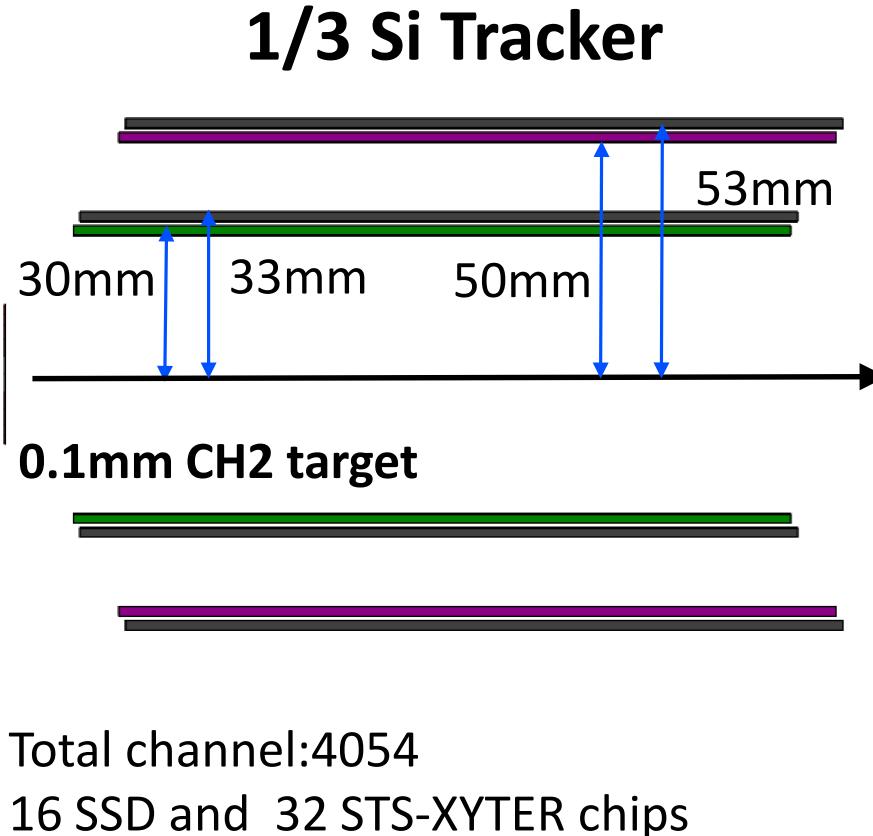
1) Missing mass spectroscopy ($p, 2p$) and ($p, p\alpha$)



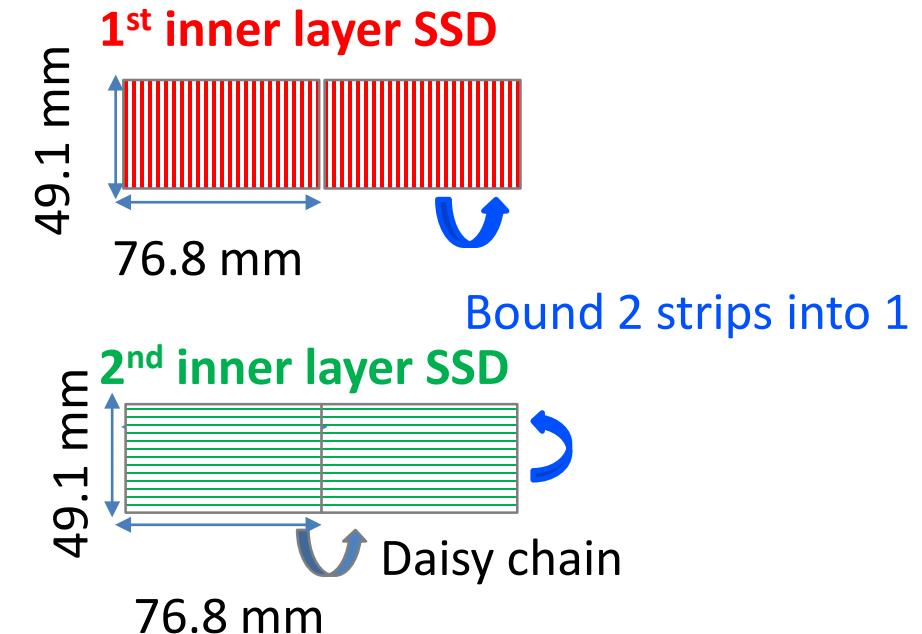
Thin CH_2 target for high resolution



PFAD: Prototype For Advanced Detector



Effective area: **49.1 mm × 76.8 mm**
Thickness: 50 μm inner layer
100 μm outer layer)
Pitch size: 100 μm

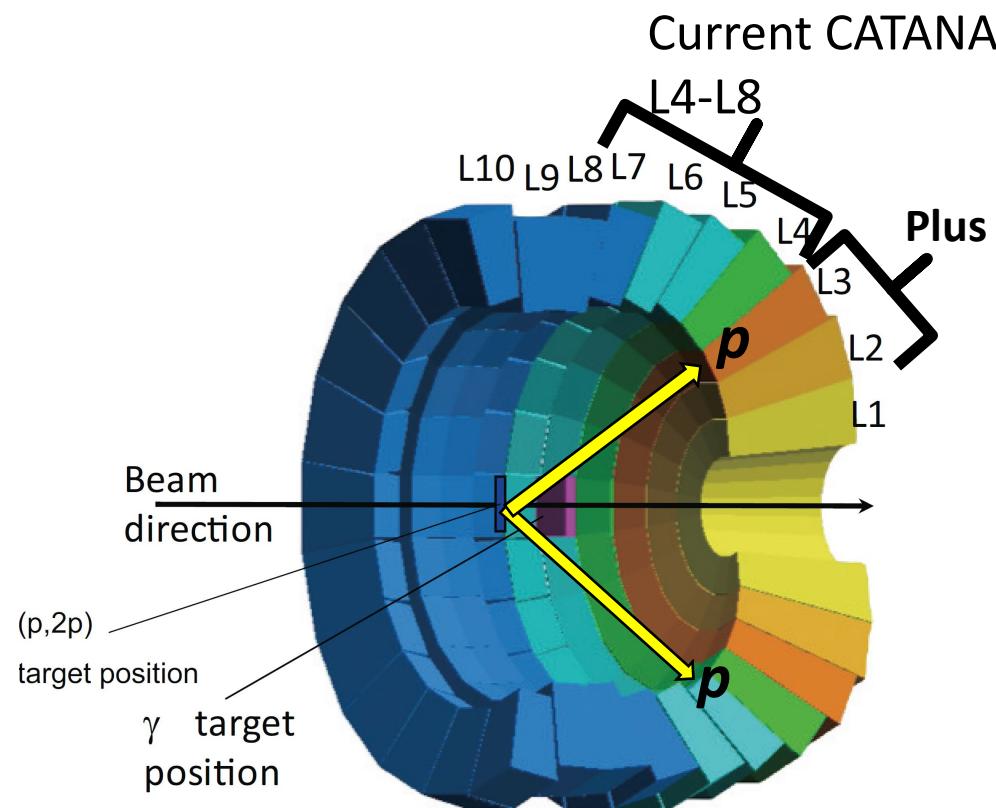


PFAD: Supporting frame

T. Tomai (TiTech) and R. Gernhaueser (TUM)

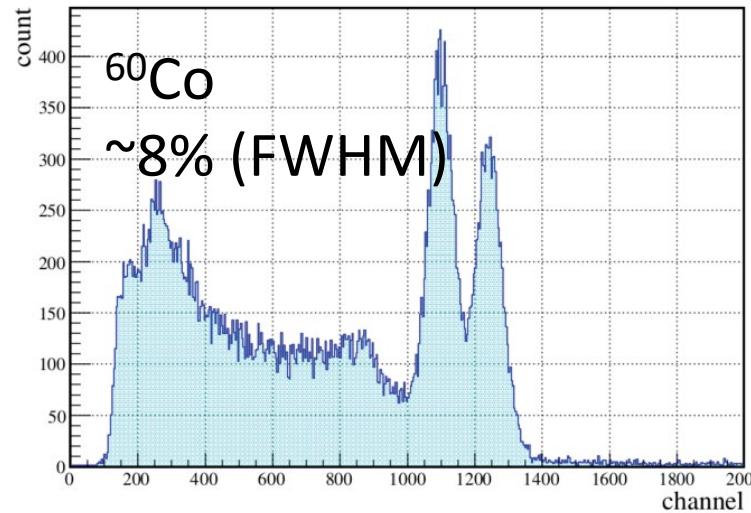
CATANA plus

Cesium iodide Array for γ -ray Transitions in Atomic Nuclei at high isospin Asymmetry
→ Originally designed for γ -ray calorimeter: 200ch CsI(Na) Planned

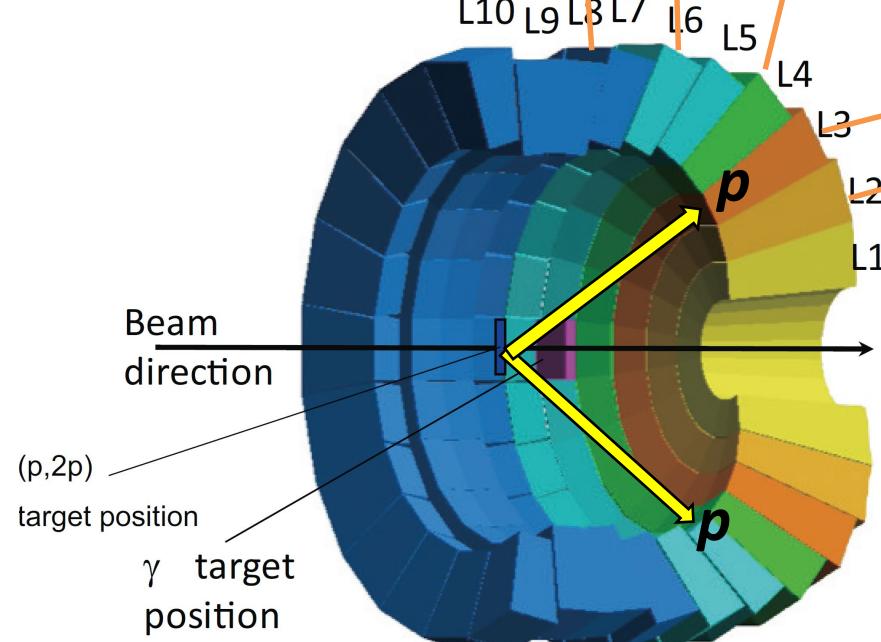
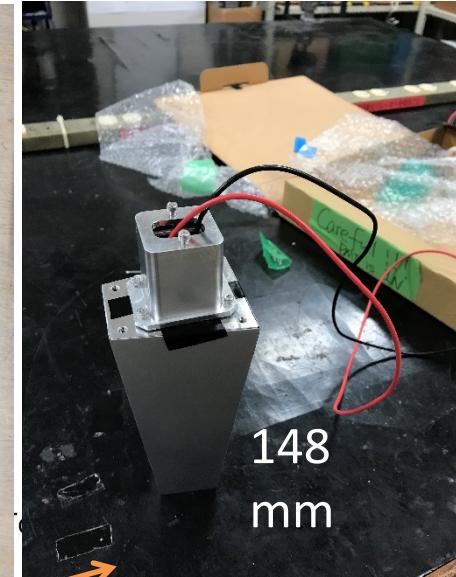
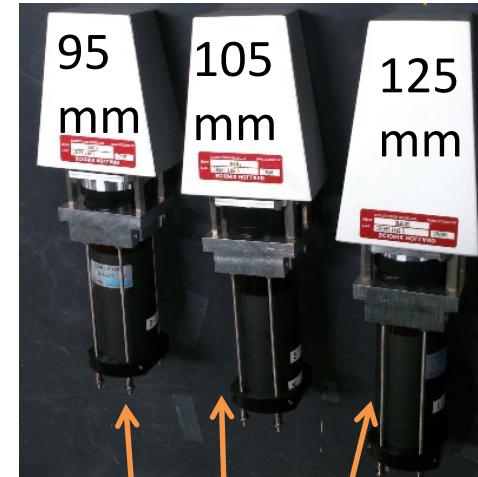


	Current	CATANA plus
Channels	100	140
Layers	L4-L8	L2-L8
Angle coverage [deg]	40-71	14-71
2p efficiency [%]	18	51

CATANA plus



N. Ebina, Bachelor thesis



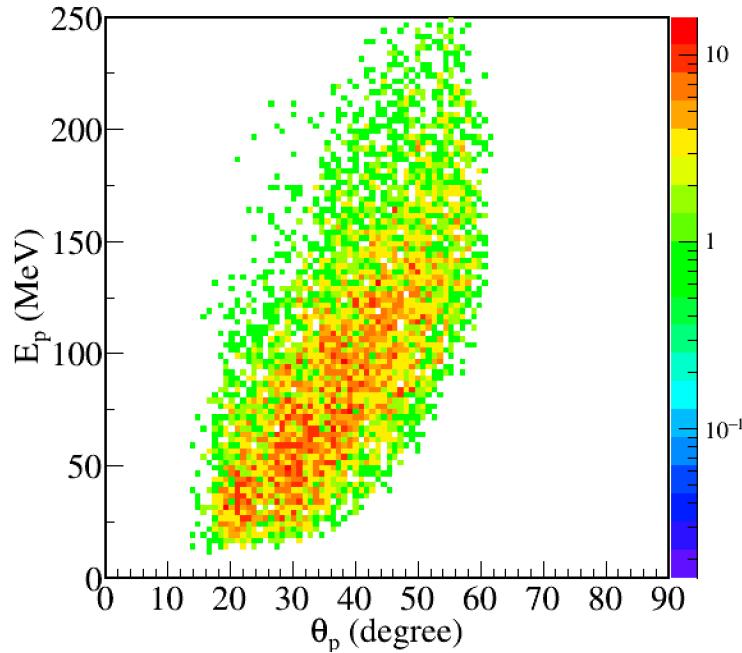
- Test on prototype CsI for L2 and L3
- Ready by 2020.12

PFAD and CATANA plus: Efficiency and Resolution

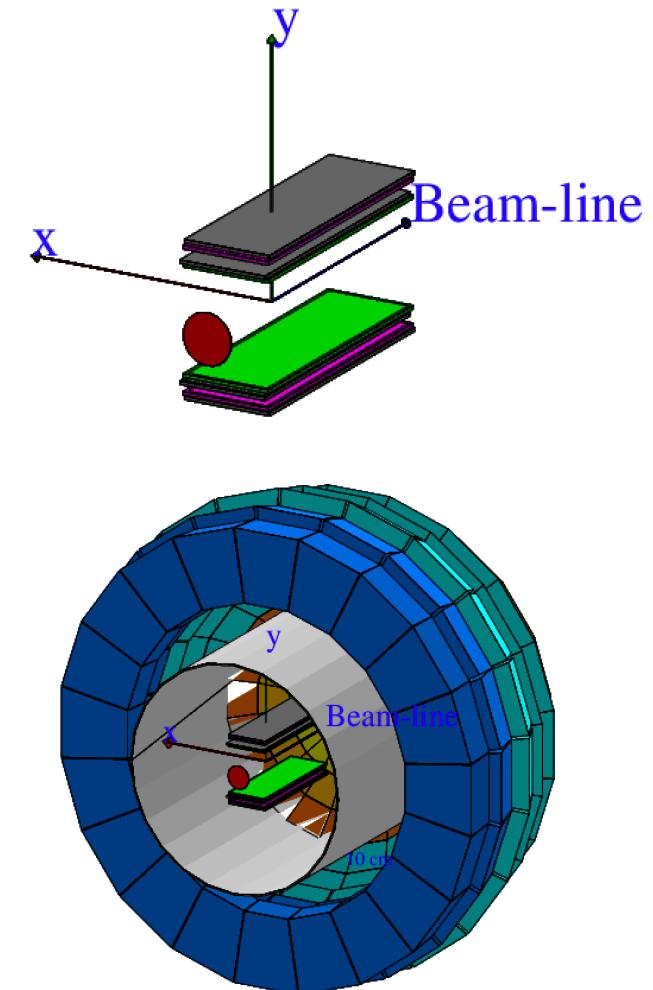
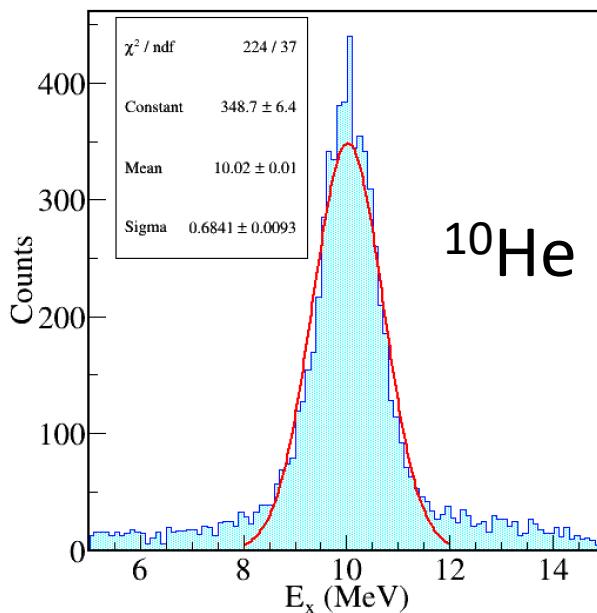
$^{11}\text{Li}(p,2p)^{10}\text{He}$ @ 200 MeV/u

Simulation results

2p coincidence eff. ~7.%



Resolution: 0.7 MeV (σ)



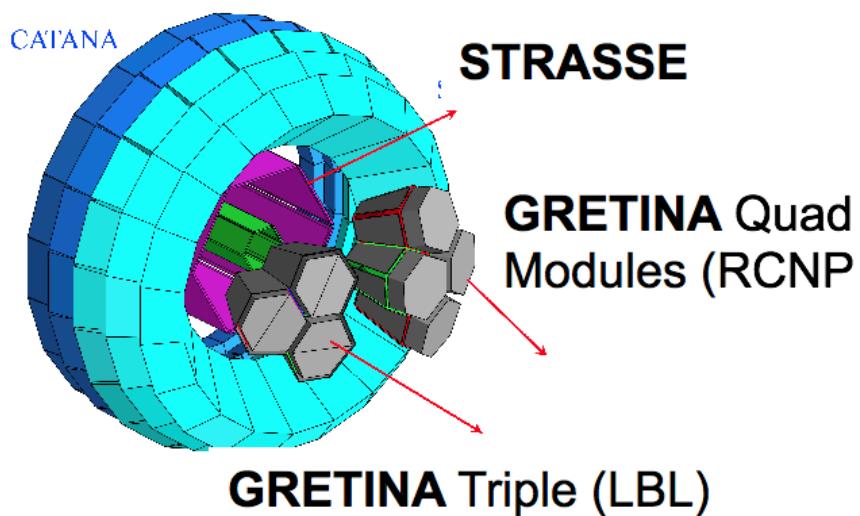
Perspective

Physics program at SAMURAI using ($p, 2p$) reactions:

2) High resolution γ -ray spectroscopy

STRASSE+ CATANA + LH2 target

+High resolution gamma ray tracking detectors



Summary

- Search for multi-neutron state in ^{10}He
- Approved experimental program at RIBF, RIKEN
- Development on new device for (p,2p) with missing mass
STRASSE/PFAD and CATANA plus

Collaborators

- TU Darmstadt: A. Frotscher, H. N. Liu, A. Obertelli, Y. L. Sun
- TiTech: N. Ebina, Y. Kondo, T. Nakamura, T. Tomai, H. Wang
- TU München: R. Gernhaeuser, B. Michael 
- RIKEN: H. Otsu, M. Sasano, T. Uesaka 
- Rikkyo U.: Y. Togano 
- GSI : J. Haueser, C. Schmidt 
- LPC: F. Flavigny 



Thank you